

UNITED STATES PATENT APPLICATION

of

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for

TIW PLATINUM INTERCONNECT AND METHOD OF MAKING THE SAME

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BACKGROUND OF THE INVENTION

The invention relates to the field of interconnects or electrodes for integrated MEMS

5 devices.

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Integrated microelectromechanical systems (MEMS) devices are monolithic (single-chip) MEMS devices that contain electrodes with sensing, control or processing circuitry. The production of integrated MEMS devices is based, in large part, upon well-developed techniques in the disciplines of integrated circuit semiconductor manufacturing and photolithography. As such, these devices use metal interconnects/electrodes similar to those for traditional integrated devices. Optical MEMS (such as a micro-mirror for fiber-optic switching), however, require metal interconnects that provide a noble metal surface in the bond pads for epoxy bond. In addition, stress requirements for optical MEMS preclude the use of passivation films over the interconnects. Therefore, the metal of the interconnect must be inert. Similarly, Bio-MEMS devices (such as a DNA analysis chip) require electrodes that are corrosion resistant in the context of exposure to biological substances. These requirements are not met by traditional interconnects/electrodes, such as copper or aluminum interconnects/electrodes produced in standard integrated circuit (IC) processing facilities.

Therefore, the present invention provides a metallization stack utilizing platinum as a

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noble metal for use in integrated MEMS devices, particularly optical MEMS and Bio-MEMS devices. The present invention also provides a method of patterning platinum.

SUMMARY OF THE INVENTION

In one aspect of the present invention, a metallization stack is provided for use as a contact structure in an integrated MEMS device. The metallization stack comprises a titanium-tungsten layer that operatively contacts an electrically conductive structure in the integrated
5 MEMS device, and a platinum layer formed over the titanium-tungsten layer.

In another aspect of the present invention, a method of forming a metallization stack for use as a contact structure in an integrated MEMS device is provided. The method comprises forming a titanium-tungsten layer that operatively contacts an electrically conductive structure in the integrated MEMS device, and forming a platinum layer over the titanium-tungsten layer.

10 In another aspect of the present invention, an integrated MEMS device comprising a metallization stack having a contact layer of platinum and an adhesion layer of TiW is provided.

15 In another aspect of the present invention, a method is provided for patterning platinum for fabricating a semiconductor device. Platinum is deposited on a semiconductor substrate. An oxide hardmask is deposited on the platinum. The oxide hardmask is patterned and etched to leave oxide in the areas patterned platinum is to be formed. The exposed platinum is then etched using a combination dry and wet etch, and after the platinum is etched the hardmask is removed.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a platinum (Pt) metallization stack used to contact active silicon elements that are part of an integrated MEMS device.

5 Figure 2 illustrates a method to form a metallization stack for use as a contact structure in

an integrated MEMS device.

Figure 3 illustrates a method for patterning platinum.

Figures 4a-4d illustrate the results of various steps illustrated in Figures 1 and 2.

Figure 5 illustrates an alternate method to form a metallization stack for use as a contact structure in an integrated MEMS device.

10 Figure 6 illustrates the Pt metallization stack used as a MEMS electrode that has been monolithically integrated into a standard silicon semiconductor circuit.

DETAILED DESCRIPTION OF THE INVENTION

A Pt metallization stack is used in integrated MEMS devices so as to provide benefits over prior integrated MEMS interconnect/electrode structures. In one embodiment, the Pt metallization stack is used as an interconnect to contact active silicon elements that are part of an integrated MEMS device. In this case, the Pt is used because stress or bonding requirements require an unpassivated metal or a noble metal for packaging. In another embodiment, the Pt metallization stack is used as an electrode that is monolithically integrated into a standard silicon semiconductor circuit of the integrated MEMS device. The Pt metallization stack is used in this case for MEMS applications that require a corrosive resistant electrode. In addition to the advantages provided by Pt's noble qualities, Pt is particularly advantageous because it is compatible with standard integrated circuit processing facilities. Figure 1 illustrates a platinum

(Pt) metallization stack used to contact active silicon elements that are part of an integrated MEMS device. Optical MEMS devices requiring a noble metal for bonding are exemplary integrated MEMS devices using the Pt metallization stack in this manner. As shown, a silicon substrate **100** has an active silicon element **110** formed in it. A Pt interconnect **108** contacts the active silicon element **110** via a Titanium-tungsten (TiW) adhesion layer **106** and platinum silicide layer **104**.

Figure 2 illustrates a method to form a Pt metallization stack to contact active silicon elements in an integrated MEMS device. A field oxide is deposited on a substrate of silicon, the field oxide is patterned and etched to form holes at the contact area, and the photoresist from this process is stripped **200**. Next, a layer of platinum is deposited on the wafer, and a silicide layer is formed from the platinum on the silicon substrate at the bottom of the contact hole to create a $\text{Pt}_x\text{-Si}$ contact and the field platinum is stripped in aqua regia **202**. A result of these steps is illustrated in figure 4a. As illustrated, a silicon substrate **400** has a field oxide layer **402** on the surface of substrate **400**, which has a hole **401** at the contact area. A $\text{Pt}_x\text{-Si}$ contact **404** is formed in the contact area by creating a silicide layer on the silicon substrate at the contact area.

TiW, preferably in the proportion of 10% titanium-90% tungsten, is utilized as an adhesion layer and a barrier layer. This TiW is next deposited on the wafer. A layer of AlCu is deposited on the TiW layer as a hardmask, patterned and etched **204**, such that a layer of TiW will be left over the $\text{Pt}_x\text{-Si}$ contact. The photoresist from the etching of the AlCu is then removed **206**. Wet etching is performed on the TiW layer to form the TiW adhesion/barrier layer over the $\text{Pt}_x\text{-Si}$ contacts utilizing the AlCu hardmask **208**. The AlCu hardmask is then removed via a wet etch process **210**. A result of these steps is illustrated in figure 4b. As shown, a TiW layer **406** is formed over $\text{Pt}_x\text{-Si}$ contact **404**.

Finally, a platinum layer is formed over the TiW layer 212, preferably utilizing the method illustrated in Figure 3. Platinum is deposited utilizing any known technique on the wafer 300. An oxide hard mask is then deposited on top of the platinum 302. The oxide hardmask is then patterned and etched utilizing standard photolithography and etch techniques 304. In such techniques, a photoresist is applied to the hardmask and formed into the desired pattern, exposing portions of the hardmask. The entire structure is then exposed to an etchant, which etches away the exposed portions of the hardmask. After the exposed portions have been etched, the photoresist is removed 306. As shown in Figure 4c, these steps result in deposited platinum 408 covering field oxide 402 and TiW layer 406 along with a patterned oxide hardmask layer. An area of the oxide hardmask 410a covers the area on which the platinum is to be retained to form a platinum layer over TiW layer 406. It should be noted that, preferably, oxide hardmask area 410a is oversized from TiW layer 406 to prevent exposure of TiW layer 406 to a subsequent wet etch in aqua regia.

The platinum is then etched using a combination of dry and wet etching 308 to remove the exposed areas of deposited platinum 408. Once the platinum has been etched, the oxide hardmask is removed using either a dry or wet oxide etch 310.

For the etching of deposited platinum 408, first the dry etching is performed by sputter etching in, preferably, Argon. As is well known in the art, sputter etching utilizes ionized particles of a charged gas plasma to bombard the surface of a substrate, in this case the platinum, to etch away or "sputter" substrate particles from the surface of the substrate. In sputter etching, a plasma gas, in the present case preferably argon, is typically introduced into the processing space of a processing chamber. The substrate to be etched is electrically charged or biased. Energy is coupled to the gas, which ionizes the gas particles so that they acquire a net charge that

is of opposite polarity to the charge of the substrate. The ionized particles of the gas collectively form a gas plasma or plasma cloud. The charge of the ionized particles of the plasma is opposite that of the substrate, and therefore, the ionized particles in the plasma are attracted to the substrate surface. As a result of this attraction, the ionized particles bombard the surface and dislodge material particles to etch the substrate. Once this is completed, the etching of the platinum is continued by a wet etch of the platinum in aqua regia. As is well known, wet etching comprises immersing the structure in a liquid bath of a chemical etchant, which is preferably aqua regia.

The final contact structure from these steps is illustrated in figure 4d. A platinum layer 10 **408** is formed, under which is TiW adhesion/barrier **406** layer formed over Pt_x-Si contact area **404**.

When platinum layer **408** is a portion of platinum wiring (interconnect) formed on field oxide layer **402**, or when platinum wiring is formed on field oxide layer **402** in addition to the contact structure, the platinum patterning method is preferably utilized to form both platinum layer **408** and the platinum wiring simultaneously. This is additionally illustrated in Figures 4c and 4d. As shown in figure 4c, in addition to oxide hardmask area **410a**, an oxide hardmask area **410b** covers deposited platinum **408** in an area where platinum wiring is to be formed. After the etching of the deposited platinum **408** and removal of the patterned oxide hardmask, platinum-wiring **412** is left on field oxide layer **402**, as shown in figure 4d.

Figure 5 illustrates an alternate method to form the Pt metallization stack to contact active silicon elements in an integrated MEMS device. In this alternative, TiW layer **406** and Pt layer **408** are deposited sequentially and patterned simultaneously by plasma etch, using a photoresist as a mask. As shown, the process is the same as that of figure 1 up to step **102**.

After step 102, TiW is deposited on the surface of the substrate 504. Platinum is next deposited on top of the TiW 506. The platinum and TiW are then patterned using a photoresist mask 508 and simultaneously etched using a single plasma etch 510.

Figure 6 illustrates the Pt metallization stack used as a MEMS electrode that has been monolithically integrated into a standard silicon semiconductor circuit. Bio-MEMS devices used to handle corrosive or harsh fluids are exemplary integrated MEMS devices using the Pt metallization stack in this manner. As shown, an active silicon device 600 has conventional integrated circuit interconnections 602 with a passivation layer 604. Pt electrode 606 contacts conventional interconnect 602 via TiW adhesion layer 608. When used in this application, the metallization stack is formed by either the method described in figure 2 or 5, absent steps 202 and 204 because the platinum silicide is not used to contact conventional interconnect 602.

Although the present invention has been shown and described with respect to several preferred embodiments thereof, various changes, omissions and additions to the form and detail thereof, may be made therein, without departing from the spirit and scope of the invention. For example, the platinum patterning technique is not limited to use with the metallization scheme described herein, but rather is appropriate for the formation of any patterned platinum features required for the fabrication of a semiconductor device. In addition, while the metallization scheme of the present invention is particularly advantageous for optical MEMS devices and Bio-MEMS devices, it should not be construed as limited thereto, but rather it is appropriate for integrated MEMS devices in which a noble metal is advantageous for interconnects/electrodes.

What is claimed is: